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Semi-Automatic Hand-Operated Spud Welder

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SEMI-AUTOMATIC HAND-OPERATED SPUD WELDER

for

PROFESSOR DONALD J. McALEECE

INDIANA UNIVERSITY - PURDUE UNIVERSITY

at FORT WAYNE

by

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APRIL 17, 1985

DESCRIPTIVE ABSTRACT

The semi-automatic hand-operated spud welder will use the metal-inert gas (MIG) welding process to weld spuds that will range from 3/4-inch to 3 inches. Since this device is hand operated, it must weigh less than ten pounds. This device will enable a worker who has little or no welding experience to successfully complete this welding procedure.

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INFORMATIVE ABSTRACT

Welding plays a large role in the manufacturing of water tanks. Several spuds are welded to the surface of a tank during production. Spuds are welded by hand--requiring skilled welders. These welders must maintain three very critical variables throughout each welding operation. They are arc distance, arc angle, and arc velocity. These variables must be maintained properly to produce a quality weld.

The semi-automatic hand-operated spud welder is a full-scale working prototype. The critical variables stated are properly maintained through the use of a two-linkage mechanism and a D.C. gearmotor. This automatically rotates a MIG torch around the circumference of the spud during the welding process. The prototype weighs less than ten pounds, and with proper adjustments, welds a spud size range of 3/4-inch to 3-inches. The prototype uses an available power source and wire feed, which is used throughout Quick Tanks today. This enables a quick and easy change-over between the present setup and the prototype.

This report discusses the design and analysis of the working prototype. The technical plan is broken down into the design solution, fabrication, testing, and cost analysis. The design solution contains the general description, design criteria, and design analysis. The fabrication section lists

the machinery used to produce the working prototype. The testing section evaluates each of the criterion stated. The materials list, along with a cost breakdown, is listed in the cost analysis. This report is then summarized, and the advantages and disadvantages are explained.

INTRODUCTION

BACKGROUND

Many processes take place as steps in the production of water tanks. The process in use today has no fully automated manufacturing and has but a few semi-automated processes. Therefore, most operations are performed by a group of skilled workers. The few semi-automated processes used today in the production of water tanks incorporate the submerged-arc welding process. However, this process is used in only two of the three welding procedures needed to complete the tank.

Process number three has not been automated and is completed by a skilled welder. In this process, a spud is welded onto the outer shell of a water tank. As shown in Figure 1, a spud is a pipe fitting which has a pipe thread on the inside. This enables a plumber to tap directly

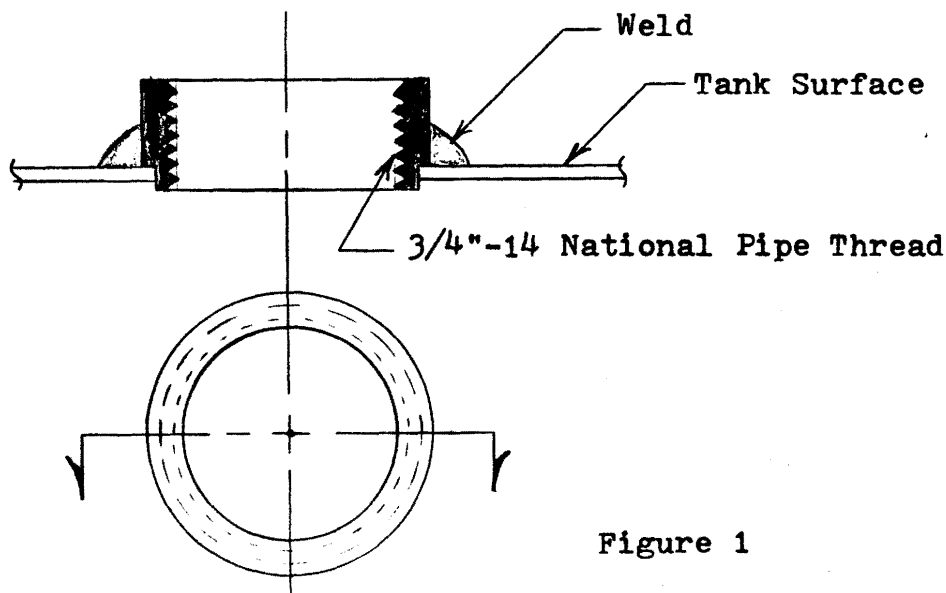


Figure 1

into the tank while constructing a basic water system. If this third manufacturing process could be semi-automated, the valuable time in which the welding process takes place and the quality of the weld could be improved.

STATEMENT OF PROBLEM

When a water tank is returned by the customer because of a weld failure, it costs the company money. In this case, the company could also lose their credibility of being quality minded, and they could easily lose the customer to a competitor.

As stated, the spud welding process is completed by hand using the metal-inert gas (MIG) welding process. When a welder welds a spud onto the surface of a tank, three very critical variables must be maintained throughout this procedure. These variables are as follows:

- 1) The proper arc distance must be maintained;
- 2) The proper arc angle must be maintained; and
- 3) The proper arc velocity must be maintained.

If any one of these three variables are not properly maintained, the quality of weld will be very poor. Therefore, it takes a skilled welder with a very steady hand to perform this operation. Even he may have problems staying consistent during eight hours of production.

OBJECTIVE

The semi-automatic hand-operated spud welder has been designed, built, and tested as a full-scale working prototype in accordance with the following requirements:

- 1) Requirements set forth by MET 497, Senior Project;
- 2) Requirements set forth by W421, Senior Technical Writing; and
- 3) Requirements set forth by the designer to fulfill the design criteria stated in the following report.

TECHNICAL PLAN

The technical analysis consists of five parts:

1. Design solution
2. Fabrication
3. Testing
4. Cost analysis
5. Summary

DESIGN SOLUTION

General Description

The semi-automatic hand-operated spud welder uses the metal-inert gas (MIG) welding process. Figure 2 illustrates the MIG welding process. The MIG process uses a continuously fed consumable electrode for filler metal and an externally supplied gas for shielding which protects the molten metal from chemically reacting with the atmosphere.

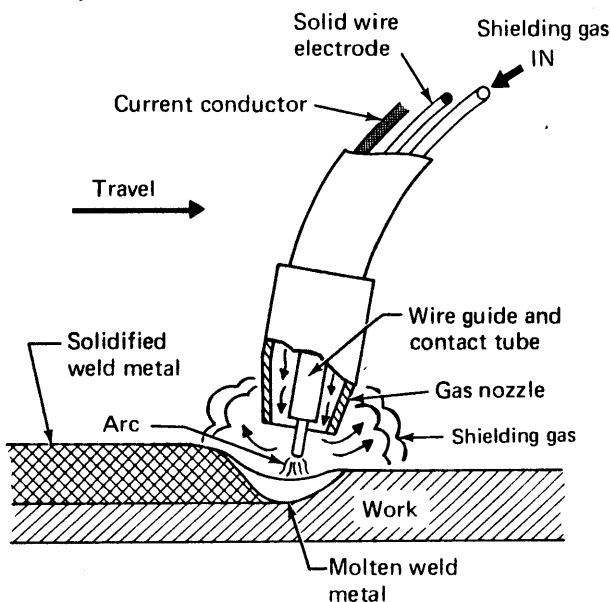


Figure 2

A Lincoln R3S-250 D.C. power source and a Lincoln LN-7 wire feed shown in Figure 3 are readily available setups used at Quick Tanks today. This setup uses a Tweco No. 4 MIG gun (Appendix H) which is used throughout the plant for welding spuds. The semi-automatic hand-operated spud welding prototype also adapts into the available power source package. This enables a quick and easy changeover between the Tweco MIG gun and the spud welding prototype.

The semi-automatic hand-operated spud welder rotates a MIG torch around the outer circumference of the spud; however, the person operating this device stands stationary, pulls the power trigger, and the device tracks around the spud requiring very little upper body movement. This is accomplished through the use of a two-linkage mechanism shown in Figure 4.

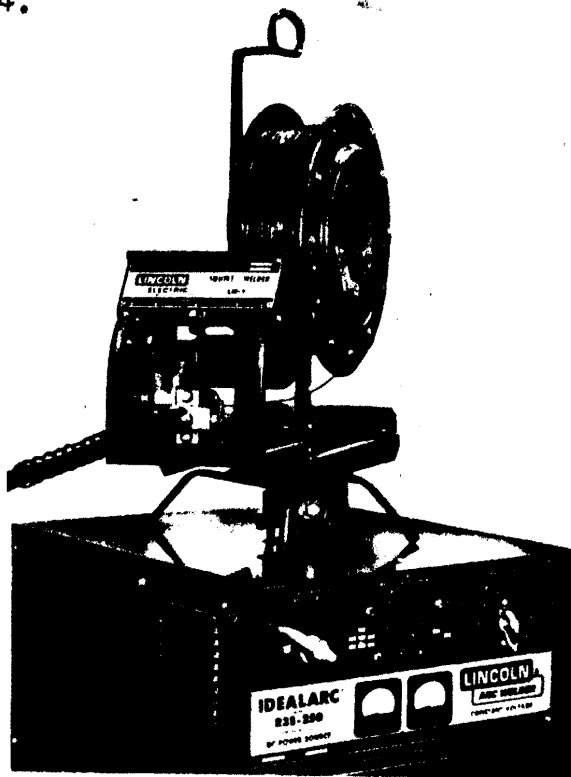


Figure 3

Side View

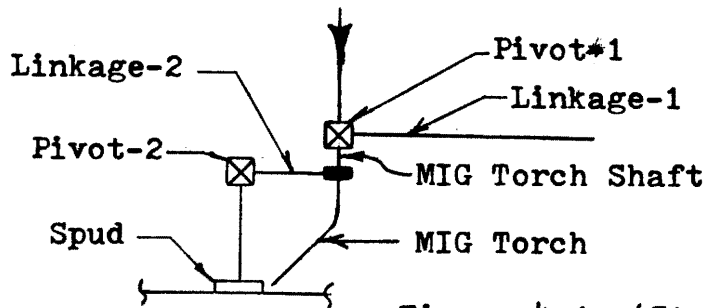
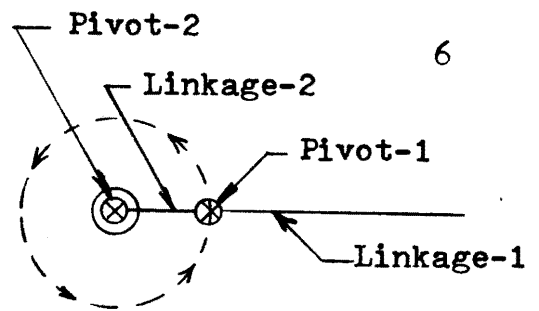


Figure 4-A (Start)

Top View



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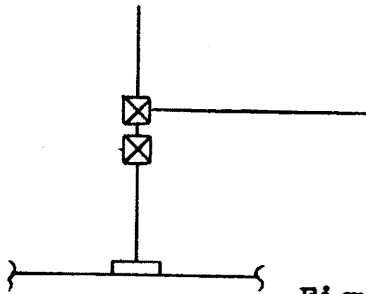


Figure 4-B (90° In Progress)

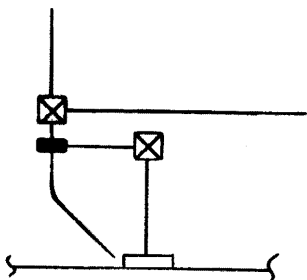
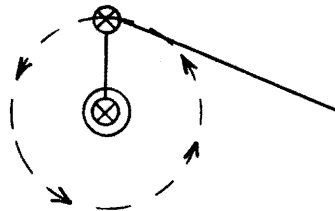


Figure 4-C (180° In Progress)

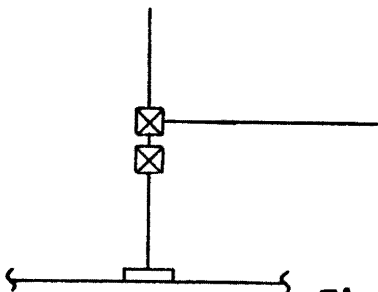
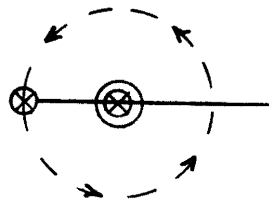


Figure 4-D (270° In Progress)

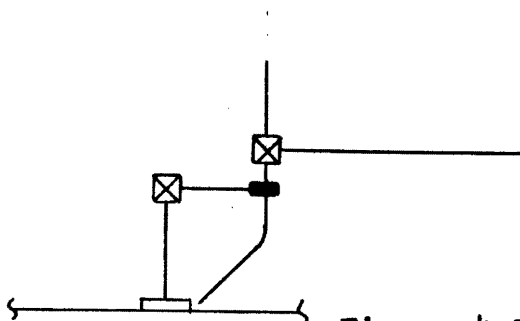
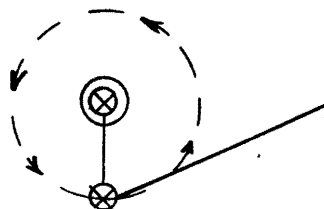
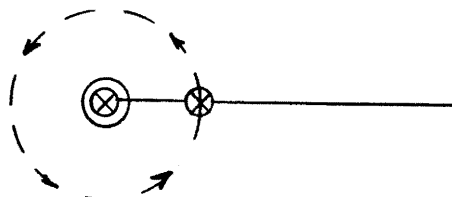


Figure 4-E (360° Finish)



Linkage No. 1 represents the main housing. The main housing is a welded construction made of 6061-T6 aluminum $\frac{1}{4}$ -inch plate (Appendix K).

Two plastic Thomson Nyloner bearings (Appendix I) provide Pivot No. 1. The two bearings are press fit into the main housing. The MIG torch shaft (Appendix L) runs through the bearings and clamps fast to the connecting arm which is Linkage No. 2.

Linkage No. 2 (connecting arm) is a $\frac{5}{8}$ -inch x $1\frac{1}{4}$ -inches 6061-T6 aluminum bar (Appendix M). This linkage rotates a full 360° in one welding operation. As shown in Figure 4, the MIG torch shaft is clamped to the connecting arm which enables the MIG torch (Appendix L) to rotate the same 360° . The connecting arm is adjustable horizontally to accommodate different diameter spuds as is the clamp that holds the MIG torch shaft for vertical adjustment.

A Boston flanged typed bronze bearing is used for Pivot No. 2 (Appendix J). The whole device pivots about this point. The guide post (Appendix N) fits into the bronze bearing at the top end and fits into the spud plug on the bottom end. The spud plug (Appendix N) fits snugly into the spud to be welded.

The MIG torch and the MIG torch shaft are both made of copper that passes the welding current to the contact tip that is at the end of the MIG torch. Therefore, the

device must be insulated to avoid an electrical short through the steel water tank which is grounded in a basic welding circuit. The Thomson Nyliner bearings insulate the main housing while the clamping block (Appendix M) made of Delrin plastic insulates the connecting arm.

The drive system which rotates the device is shown in Figure 5 and is enclosed in the main housing. The main bevel gear is a 32-pitch, 16-tooth plastic bevel pinion gear. A plastic gear is needed to insulate the D.C. drive motor from the welding current which would be passing through the brass main bevel gear during the welding operation.

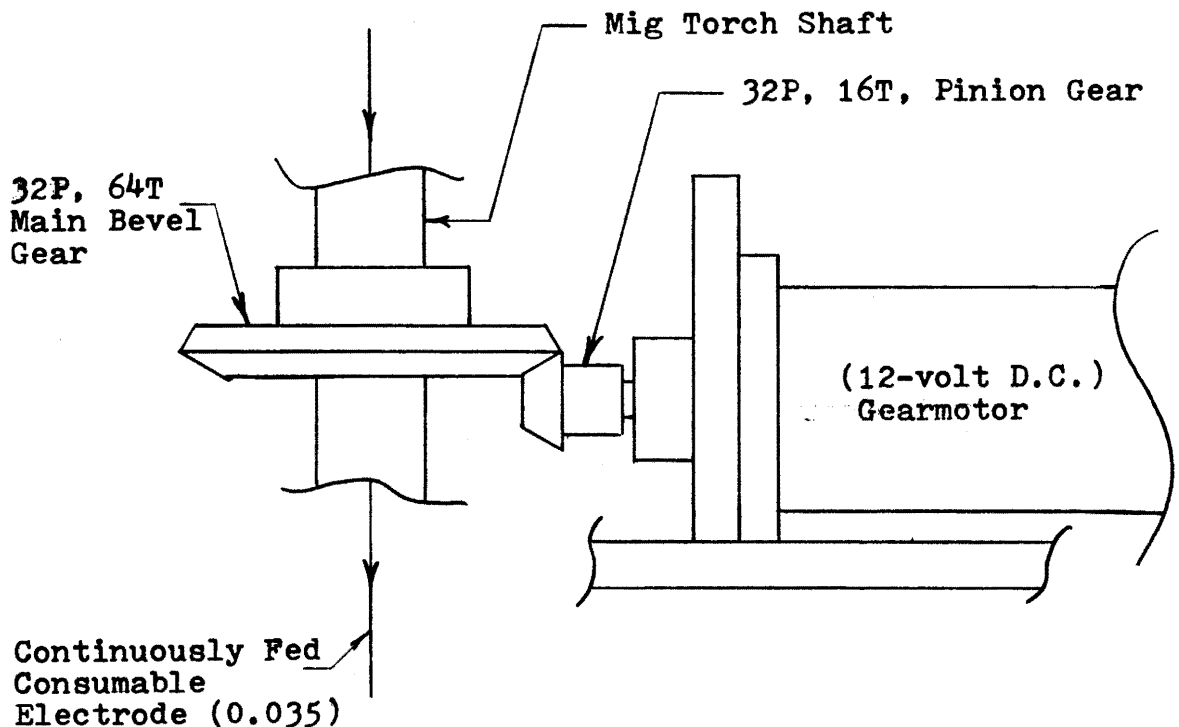


Figure 5

A D.C. permanent magnet planetary gearmotor was purchased from TRW Motors (Appendix G). This gearmotor, which drives the plastic pinion gear, is a variable speed, reversible motor. It was chosen because of its small diameter (1-3/16 inches) and its light weight (12 ounces). The gearmotor satisfactorily meets the torque and speed requirements (Appendix A).

The consumable wire used in the MIG welding process is 0.035-inch diameter. Argon is used as the shielding gas. These two items (wire and gas) pass through the MIG torch shaft down to the welding contact tip in the direction shown in Figure 4-A. The welding current also passes through to the contact tip. A special cable made by Tweco Welding Products, Incorporated called "cablehoz" is designed to pass the wire, gas, and welding current through to the Tweco No. 4 MIG gun. This same cable was used in the design of the spud welder; however, it could not hook directly into the MIG torch shaft because with each revolution of the device, the cablehoz would slowly twist into a knot. Two solutions to this problem are: 1) The operator could weld one revolution then trigger the reversing switch and weld in the opposite direction during the next revolution; or 2) A rotating union could be designed that would pass the wire, gas, and current and allow the cablehoz to stay stationary throughout each and every welding operation.

✓

A rotating union was designed so the operator could run the device in either direction. The main components of this union are as follows: 1) Two highly conductive Beryllium Copper alloy contacts; 2) A housing made from Delrin plastic for insulating; and 3) A spring to keep the two contacts forced together. An assembly drawing is shown in Appendix O. The rotating union is connected to the MIG torch shaft and is located directly above the main housing. As the MIG torch shaft rotates, the bottom contact rotates. The top contact is held stationary and is forced downward by the spring load and makes contact with the bottom contact. The union passes wire, gas, and the welding current and does so without the cablehoz (which is connected to the top contact) twisting in either direction. This enables the operator to weld in one direction continuously.

The prototype has three electronic controls on the cover plate which fastens to the main housing. These are as follows: 1) Echlin on-off switch; 2) Echlin double pole, double through reversing switch; and 3) Archer 5000 ohm potentiometer.

The on-off switch is spliced into the trigger switch circuitry (Appendix E) which controls the on-off mode of the welder. When the trigger switch on the prototype is activated, the welding process begins; however, the proto-

type on-off switch must be on.

The reversing switch (Appendix E) controls the direction of the D.C. gearmotor. This switch has three modes. They are on (cw), off, and on (ccw). It is energized only when the trigger switch on the prototype is activated.

The speed at which the device rotates is controlled by a 5000 ohm potentiometer. This regulates the amount of voltage (Appendix E) supplied to the D.C. gearmotor from zero to twelve volts. The gearmotor RPM increases proportionally with an increase in voltage. A computer program (Appendix F) was designed which computes the RPM for any supplied voltage up to twelve volts. The data generated by this program helps to select the correct gear ratio needed to obtain the desired gearmotor RPM (Appendix A). The gearmotor selected has a ratio of 320 to 1 (Appendix G).

An additional 12-volt D.C. power source is needed for the prototypes operation. This 12-volt D.C. power source which fits inside an 8-inches x 6-inches x $3\frac{1}{2}$ -inches steel enclosure (NEMA CODE) is designed to bolt on the side of the Lincoln LN-7 wire feed. The LN-7 supplies the enclosure with 115-volt A.C. power. That power is transformed to 12-volt A.C., which in turn is rectified to 12-volt D.C. The 12-volt D.C. is then regulated and supplied to the prototypes D.C. gearmotor.

Design Criteria

1. Weigh ten pounds or less. This device will be handled for one welding operation to another. Therefore, it must be lightweight to help in the ease of operation.

2. Proper arc distance maintained consistently. This distance is measured from the contact tip to the base metal of the spud and tank surface. This distance must be maintained consistently throughout the circular motion of the welding procedure to obtain a quality weld.

3. Proper arc angle maintained consistently. This angle is measured as the angle the MIG torch makes in relation to the tank surface. This angle must be maintained consistently throughout the circular motion of the welding procedure to obtain a quality weld.

4. Proper arc velocity maintained consistently. The velocity is measured in RPM or inches per second, which is the speed at which the contact tip moves around the circumference of the spud. This velocity must be maintained consistently throughout the circular motion of the welding procedure to obtain a quality weld.

5. Weld 3/4-inch spud through 3-inch spud. The prototype will universally be used to weld a spud size range of 3/4, 1, 1½, 1¾, 2, and 3.

6. Welds must withstand a 75 psi load. This standard is set forth by the Domestic Water Tank Manufacturers Council for hydro pneumatic tanks.

7. Use existing D.C. power source and wire feed.

The Lincoln R3S-250 D.C. power source and the Lincoln LN-7 wire feed must be used with this prototype. This package is readily available at Quick Tanks today.

Design Analysis

The design analysis of the semi-automatic hand-operated spud welder consists of the following concluded experiments and design calculations:

1. Gearmotor requirements. An experiment was conducted to determine the amount of torque needed to rotate the prototype. A free rotating model was constructed using a Snap-On Torqometer RT-1600 ounce-inch torque meter as Linkage No. 1 as shown in Figure 4. After applying the needed resistance, it was determined that one foot-pound of torque would be sufficient in rotating the device.

An experiment was conducted to determine the speed requirements. With the use of a stop watch, several times were taken from hand welding experiments. From this data and calculations shown in Appendix A, an arc velocity of .30-inch per second was determined.

A small diameter, lightweight motor was needed for this design to be functional. Knowing the required speed and torque, a motor was chosen. A D.C. permanent magnet planetary gearmotor with a torque rating of 455 ounce-inches (2.4 foot-pounds) and an output RPM of 17.5 at

12 volts was purchased from TRW Motors (Appendix G).

2. Gear train calculations. The pinion gear to be used on the gearmotor must be plastic for insulating purposes. The brass main bevel gear that it meshes with connects to the MIG torch shaft which carries the welding current. A gear ratio of 4 to 1 was determined in Appendix A. A 32-pitch, 16-tooth nylon pinion and a 32-pitch, 64-tooth brass gear were selected from Stock Drive Products. Calculations concerning the nylon pinion gear are shown in Appendix B.

3. Cotter pin calculations. A 1/16-inch diameter cotter pin was used to transfer power from the gearmotor shaft to the nylon pinion gear. Calculations concerning the cotter pin are shown in Appendix C.

4. Electrical calculations. The 12-volt power supply and motor are fused for protection from any possible amperage overload. The power supply was sufficiently fused when tied into the LN-7 wire feed as shown in Appendix E. The motor needed separate protection just after the step down transformer; this also is shown in Appendix E. This fusing protection was calculated using the motor data taken from TRW Bulletin E-2110 (Appendix D).

The 12-volt power supply and the D.C. motor controls were designed by the student. This is shown in red on the M-12381 wiring diagram of the LN-7 connection schematic (Appendix E).

FABRICATION

The semi-automatic hand-operated spud welder was designed, built, and tested as a full-scale working prototype. This procedure was carried out in full by the designer in accordance with MET 497, Senior Project. The student designed and built this working prototype on "non-company" time; however, Quick Tanks, Incorporated, did secure funds for the extensive materials list.

Facilities

All the necessary parts were fabricated in the maintenance shop at Quick Tanks, Incorporated. Several machines were used throughout fabrication and assembly; these include:

1. Monarch 16-inch metal lathe: Machined rotating union housing, copper power contacts (upper and lower), pinion gear adapter, and guide post; assorted spud plugs and handle connector tube; and bore main bevel gear and plastic bearings to size.
2. Bridgeport vertical milling machine: Milled main housing parts to size; mitered corners; machined connecting arm; bore main housing for plastic bearings; tapped rotating union housing; milled gas passages in power contacts; machined insulator clamping block and main housing cover plate; and tapped gear adapter and main bevel gear.
3. Johnson cut-off band saw: Cut all raw material to size.

4. Linde AC/DC Type 300 power supply: TIG welded aluminum main housing.

TESTING

Test 1

Criteria No. 1: Weigh ten pounds or less.

Objective: This device must be lightweight to help in the ease of operation.

Methodology: The prototype will be weighed less D.C. power source, wire feed, cablehoz, and control cable.

Equipment: Fairbanks digital readout scale, 8000-pound capacity, $\pm \frac{1}{2}$ pound.

Data: The prototype weighed nine pounds.

Evaluation: The prototype meets the ten-pound maximum weight limit as stated by Criteria No. 1.

Test 2

Criteria No. 2: Proper arc distance maintained consistently.

Objective: To determine if the arc distance is maintained throughout the welding procedure.

Methodology: An arc distance of 7/8-inch was preset. The distance was checked periodically.

Equipment: Six-inch steel rule.

Data: Checking periodically, the distance measured 7/8-inch.

Evaluation: The arc distance proved to be consistent throughout each welding operation.

Test 3

Criteria No. 3: Proper arc angle maintained consistently.

Objective: To determine if the arc angle is maintained throughout the welding procedure.

Methodology: An arc angle of 45° was preset. The angle was checked periodically.

Equipment: Steel rule protractor.

Data: Checking periodically, the angle measured 45° .

Evaluation: The arc angle proved to be consistent throughout each welding operation.

Test 4

Criteria No. 4: Proper arc velocity maintained consistently.

Objective: To determine if the arc velocity is maintained throughout the welding procedure.

Methodology: An arc velocity of 0.30-inch per second was preset (21 seconds per revolution for a $1\frac{1}{4}$ -inch spud). The seconds per revolution were checked periodically.

Equipment: Hand-held stop watch.

Data: Checking periodically, the velocity was clocked at 21 seconds per revolution.

Evaluation: The arc velocity proved to be consistent throughout each welding operation.

Test 5

Criteria No. 5: Weld 3/4-inch spud through 3-inch spud.

Objective: The adjustments on this device should accommodate 3/4, 1, 1 $\frac{1}{4}$, 1 $\frac{1}{2}$, 2, and 3-inch spuds.

Methodology: After proper adjustments, the device welded each size spud.

Equipment: Adjustable horizontal connecting arm, adjustable vertical insulator clamp, and adjustable motor speed potentiometer.

Data: Each size spud was successfully welded after proper adjustments.

Evaluation: With proper adjustments, the prototype successfully welds the stated spud sizes.

Test 6

Criteria No. 6: Welds must withstand a 75 psi load.

Objective: To test for weld failure.

Methodology: A test tank was built with one of each size spud. The spuds were plugged, and the tank was then pressurized. Soapy water was brushed over each weld. Bubbles formed if any leakage occurred.

Equipment: Spud plugs, pressurized air, and soapy water.

Data: All welds checked okay.

Evaluation: The test tank met the standards set forth by the Domestic Water Tank Manufacturers Council.

Test 7

Criteria No. 7: Use existing D.C. power source and wire feed.

Objective: The Lincoln R3S-250 power source and the Lincoln LN-7 wire feed are packages readily available at Quick Tanks, Inc. If the prototype uses this package, the cost will be cut, and the ability to interchange between the Tweco MIG gun and the prototype will be easy.

Evaluation: The Lincoln package was used and did prove to be convenient. A slight modification to the wire feed was needed for the prototype. However, this did not affect the ability to change from the Tweco gun to the prototype and vice versa.

COST ANALYSIS

The prototype cost \$341.73--well under the estimated \$500. The cost of the prototype was cut because many Tweco parts were used in the design. Many Tweco parts are stocked by Quick Tanks because of the extensive use of the Tweco No. 4 MIG gun. The cost of the Lincoln R3S-250 D.C. power source and the Lincoln LN-7 wire feed were also excluded in the prototype cost. They were excluded due to their availability and ease of changeover between the prototype and Tweco No. 4 MIG gun.

The actual cost would be \$598.88. This cost includes the prices of all materials that were taken from stock. However, this does not include the power source or wire feed.

Quick Tanks, Inc., secured all funds for the extensive materials list shown on the next page. However, this project was design, built, and tested on "non-company" time; therefore, \$341.73 was the total cost incurred by Quick Tanks.

MATERIALS LIST

<u>#</u>	<u>Reqd.</u>	<u>Description</u>	<u>Part #</u>	<u>\$ Prototype</u>	<u>\$ Actual</u>
		(Tweco MIG components)			
1		Conductor tube extension 4" long	64A-4EX	18.00	18.00
1		Conductor tube extension 6" long	64A-6EX	19.17	19.17
1		Nozzle 1/2" ID	24A-50	stock	2.40
1		Nozzle insulator	34A	stock	1.17
1		Gas diffuser	54A	stock	2.43
1		Contact tip 0.035 wire	14-35	stock	.40
1		Handle case w/ binder screws	84A	stock	23.35
1		Trigger switch complete	94R	stock	7.70
1		12" cablehoz support gun	144-12	stock	7.30
3		Cable connector block w/ screws and separator	104	stock	46.35
1		Wire conduit assembly 18" long 1/16 ID	44-116	stock	2.10
2		Diffuser set screw	44C	stock	.34
1		15' cablehoz	400-15	91.58	91.58
2		Connector case w/ binder screws	185	stock	32.30
1		Connector plug w/ O-rings	174	stock	7.83
2		Cablehoz support-connector	234-12	stock	11.70
1		15' wire conduit assembly 1/16 ID	44-116-15	stock	9.90
2		Gas hose nipples	64N	stock	.96
1		Tweco adjustable rack	---	stock	35.00
(All the above purchased from Welder Services, Inc., distributor for Tweco Welding Products, Inc.)					
1		IM-13 planetary gearmotor 12-volt	407A6020-12	116.45	116.45
(Item above purchased from TRW Motors)					
1		32P, 64T brass bevel gear	1B3-Y32064	18.15	18.15
1		32P, 16T nylon bevel gear	1M3-Y32016A	.39	.39
(Items above purchased from Stock Drive Products)					
2		Thomson Type 8 nyliner bearing	8C24-16	2.16	2.16
1		Boston bronze bearing	FB812-5	1.15	1.15
(Items above purchased from Bearings, Inc.)					
1		Plastic handle	CL-2-PH	stock	1.14
(Item above purchased from Carr Lann Co.)					
1		CEMA/NEMA Type 12 steel enclosure	806-1500	stock	25.70
1		Potter & Brumfield relay	KAP11AG-24	18.78	18.78
1		Potter & Brumfield relay block	27E123	stock	5.99
1		15' 16-7 PVC control cable	708-6466	22.23	22.23
(Items above purchased from Kendall Electronics)					

<u>#</u>	<u>Reqd.</u>	<u>Description</u>	<u>Part #</u>	<u>\$ Prototype</u>	<u>\$ Actual</u>
1		2200 micro-farad capacitor		1.00	1.00
1		240 ohm resistor		.97	.97
1		1.5 amp, 40-volt voltage regulator IC chip		1.00	1.00
(Items above purchased from Pembleton Electronics, Inc.)					
1		Archer EMI filter		7.95	7.95
1		Archer 12.6-volt, 3 amp power transformer		5.99	5.99
1		Archer 5000 ohm potentiometer (linear tap)		2.40	2.40
1		Archer 3 amp, 40-volt full wave bridge		1.39	1.39
1		Mini fuse holder		.89	.89
1		1.5 amp fuse		.89	.89
1		Potentiometer knob		.25	.25
1		Heat sink		.79	.79
1		Mounting kit		.49	.49
(Items above purchased from Radio Shack)					
1		Echlin DPDT reversing switch		6.05	6.05
1		Echlin on-off toggle switch		4.76	4.76
(Items above purchased from NAPA Auto Parts)					
<u>Assorted Hardware</u>					
5		$\frac{1}{4}$ -20 x $\frac{1}{4}$ " set screw		stock	.75
8		$\frac{1}{4}$ -20 x 1" flat head screw		stock	.96
3		$\frac{1}{4}$ -20 x $1\frac{1}{4}$ " socket head cap screw		stock	.75
14		8-32 x $\frac{1}{2}$ " machine screw		stock	.35
1		8-32 x $\frac{3}{8}$ " set screw		stock	.10
4		6-32 x $\frac{3}{4}$ " machine screw		stock	.10
4		6-32 machine screw nut		stock	.15
1		$\frac{1}{2}$ -13 lock nut		stock	.15
1		1/16" dia. x $\frac{3}{4}$ " cotter pin		stock	.01
1		Compression spring $\frac{3}{4}$ " ID x 3"		stock	1.52
<u>Raw Materials</u>					
1		Motor mount (2" x $\frac{1}{4}$ " al.)			
1		Main housing (2" x $\frac{1}{4}$ " & 3" x $\frac{1}{4}$ " al.)			
1		Main housing cover (3" x 0.08" al.)			
1		Handle connector tube ($\frac{3}{4}$ " dia. al.)			
1		Guide post ($\frac{3}{4}$ " dia. al.)			
1		Connecting arm ($1\frac{1}{4}$ " x $\frac{5}{8}$ " al.)			
		(Total weight 4 lbs. @ \$1.35/lb)		stock	5.40
6		Assorted spud plugs (copper)			
1		Upper power contact (copper)			
1		Lower power contact (copper)			
		(Total weight 7 lbs. @ \$2.10/lb.)		stock	14.70
1		Gear Adapter (1040 CD steel)		stock	1.00
1		Insulator clamping block (Delrin plastic)			
1		Rotating union housing (Delrin plastic)			
2		Rotating union cap (Delrin plastic)			
		(Delrin plastic)		stock	6.00
TOTAL				<u>\$341.73</u>	<u>\$598.88</u>

SUMMARY

The semi-automatic hand-operated spud welder was design, built, and tested as a successful working prototype. The critical variables stated to produce a quality weld are easily maintained throughout the welding process using this device. This enables a person with little or no welding experience to complete the spud welding operation successfully.

The prototype, which weighs less than ten pounds, is easily adjusted to weld a spud range of 3/4-inch to 3-inches. The available power source and wire feed which is used enables quick and easy changeover between the present setup and the prototype.

The semi-automatic hand-operated spud welder has proven itself--by means of welding different sized spuds with ease and by its ability to produce quality welds. This device will become a very useful tool in the manufacturing of water tanks at Quick Tanks, Inc.

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APPENDIX A (Page 1 of 3)Torque and Speed Requirements

An experiment was conducted to determine the torque required to rotate the device. A free rotating model was constructed using a Snap-On Torqometer RT-1600 ounce-inch torque meter as Linkage No. 1, which is shown on Page 6, Figure 4. The required resistance was applied and a reading of 180 ounce-inches recorded.

$$180 \text{ oz-in} \times \frac{1 \text{ ft}}{12 \text{ in}} \times \frac{1 \text{ lb}}{16 \text{ oz}} = 0.94 \text{ ft-lb} \approx \underline{1.0 \text{ ft-lb}}$$

An experiment was conducted to determine the arc velocity. A stop watch was used to determine the start-to-finish speed of hand welding a $1\frac{1}{4}$ " spud. Data was accumulated and an average was obtained.

Average time 21 $\frac{\text{sec}}{\text{rev}}$

For $1\frac{1}{4}$ " spud
Outside diameter=2"
Circumference=2" π = 6.28"

$$21 \frac{\text{sec}}{\text{rev}} \times \frac{1 \text{ rev}}{6.28 \text{ in}} = \frac{3.34 \text{ sec}}{1 \text{ in}} \times \frac{1}{x} = \underline{0.30 \frac{\text{in}}{\text{sec}}}$$

Required seconds per revolution for each size and type spud at 0.30 in/sec arc velocity are computed as follows:

$3/4$ " forged spud:

Outside diameter= $1\frac{1}{2}$ "
Circumference= $1\frac{1}{2}$ " π = 4.71"

$$0.30 \frac{\text{in}}{\text{sec}} \times \frac{1 \text{ rev}}{4.71 \text{ in}} = 0.064 \frac{\text{rev}}{\text{sec}} \times \frac{1}{x} = \underline{15.7 \text{ sec/rev}}$$

APPENDIX A (Page 2 of 3)

1" fabricated spud: Outside diameter=1½"
Circumference=1½"π=4.71"

$$0.30 \frac{\text{in}}{\text{sec}} \times \frac{1 \text{ rev}}{4.71 \text{ in}} = 0.064 \frac{\text{rev}}{\text{sec}} \times \frac{1}{x} = \underline{15.7 \text{ sec/rev}}$$

1" forged spud: Outside diameter=2"
Circumference=2"π=6.28"

$$0.30 \frac{\text{in}}{\text{sec}} \times \frac{1 \text{ rev}}{6.28 \text{ in}} = 0.048 \frac{\text{rev}}{\text{sec}} \times \frac{1}{x} = \underline{21 \text{ sec/rev}}$$

1½" fabricated spud: Outside diameter=2"
Circumference=2"π=6.28"

$$0.30 \frac{\text{in}}{\text{sec}} \times \frac{1 \text{ rev}}{6.28 \text{ in}} = 0.048 \frac{\text{rev}}{\text{sec}} \times \frac{1}{x} = \underline{21 \text{ sec/rev}}$$

1½" forged spud: Outside diameter=2-3/8"
Circumference=2-3/8"π=7.46"

$$0.30 \frac{\text{in}}{\text{sec}} \times \frac{1 \text{ rev}}{7.46 \text{ in}} = 0.040 \frac{\text{rev}}{\text{sec}} \times \frac{1}{x} = \underline{24.9 \text{ sec/rev}}$$

1¾" fabricated spud: Outside diameter=2¼"
Circumference=2¼"π=7.07"

$$0.30 \frac{\text{in}}{\text{sec}} \times \frac{1 \text{ rev}}{7.07 \text{ in}} = 0.042 \frac{\text{rev}}{\text{sec}} \times \frac{1}{x} = \underline{23.6 \text{ sec/rev}}$$

1½" forged spud: Outside diameter=2½"
Circumference=2½"π=7.85"

$$0.30 \frac{\text{in}}{\text{sec}} \times \frac{1 \text{ rev}}{7.85 \text{ in}} = 0.038 \frac{\text{rev}}{\text{sec}} \times \frac{1}{x} = \underline{26.2 \text{ sec/rev}}$$

2" forged spud: Outside diameter=3-1/8"
Circumference=3-1/8"π=9.82"

$$0.30 \frac{\text{in}}{\text{sec}} \times \frac{1 \text{ rev}}{9.82 \text{ in}} = 0.030 \frac{\text{rev}}{\text{sec}} \times \frac{1}{x} = \underline{32.7 \text{ sec/rev}}$$

Gear Train Calculations

A nylon bevel gear was used for the pinion drive for the prototype. The safe tooth load was calculated using the revised Lewis Formula which compensates for the differences between spur and bevel gears. This equation was taken from Mechanical Engineering, third edition, by Joseph E. Shigley.

$$W = \frac{S \times F \times Y}{P} \times \frac{600}{600 + V}$$

where W = Safe Tooth Load, Lbs
 S = Safe Material Stress, Lbs/in² (12,000psi, Nylon)
 F = Face Width, in (0.265 in)
 Y = Tooth Form Factor (0.402)
 D = Pitch Diameter, in (0.50 in)
 P = Diametral Pitch (32)
 V = Pitch Line Velocity, Ft/min

$$V = 0.262 \times (D = 0.50) \times (\text{RPM} = 17.5) = \underline{2.3 \text{ Ft/min}}$$

$$W = \frac{(12,000) \times (0.265) \times (0.402)}{32} \times \frac{600}{600 + 2.3}$$

$$\underline{W = 38.5 \text{ Lbs}}$$

The safe tooth load of 38.5 Lbs is well above the gear-motor capabilities. Therefore the Nylon pinion gear may be used in the prototype.

APPENDIX C

A 1/16-inch diameter cotter pin was used to transfer power from the gearmotor shaft to the nylon pinion gear. A calculation to determine the shearing load is as follows:

$$F = S_s \times A$$

where F =Maximum load

S_s =Shearing stress (17,000 lb/in²)

A =Cross sectional area ($\pi/4 \times 1/16^2$)=0.0031 in²

$$F = 17,000 \text{ lb/in}^2 \times 0.0031 \text{ in}^2 = \underline{52 \text{ lbs.}}$$

The shearing load of 52 pounds is well over the maximum gearmotor capability. Therefore, the pin will withstand any load by the gearmotor.

APPENDIX D (Page 1 of 2)Motor Protection Calculations

Both the motor and supply lines must be protected from the flow of excessive current during the starting period. A recommended starting current is 125 percent to 200 percent of full-load current. (This is taken from Electric Circuits and Machines, Sixth Edition, by Eugene C. Lister).

The supply line to the motor, which is the step-down power transformer, is rated at 3 amps. The transformer is wired into the LN-7 power supply, which is fused at 5 amps. The following calculation justifies the use of this fuse:

$$\% I_s = \frac{I_f}{I_R}$$

where I_f = Fuse rating, amp
 I_R = Amperage rating, amp
 $\% I_s$ = Recommend percent of starting current, amp

$$\% I_s = \frac{5A}{3A} = 1.67 = \underline{167\%}$$

This falls within the required 125 percent to 200 percent.

The maximum starting current of the motor is 0.7 amps. The calculated fuse size is:

APPENDIX D (Page 2 of 2)

$$\% I_s = \frac{I_f}{I_R} \longrightarrow I_f = \% I_s \times I_R$$

$$I_f = 150\% \times 0.7 = \underline{1.05 \text{ amp}}$$

A 1.0 amp fuse will be used to protect the motor.